NOTES ON THE BEHAVIOR OF SEA-ANEMONES.[1]

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During the summer of 1901 while keeping a few sea-anemones in the aquarium for the purpose of studying their general habits, particularly those of feeding, my attention was drawn to the interesting phenomenon that certain species appeared more alert during the night, closing up more or less during the day. This was more noticeable in the large sand-anemone, *Eloactis producta*, whose peculiar habit of burrowing in the sand, enabled it to withdraw entirely when disturbed, or under other unfavorable conditions.

Having secured several specimens of this anemone they were placed in an aquarium, the bottom of which had been covered with sand to the depth of some six inches or more. The specimens, true to their habit, soon burrowed deeply in the sand, and lining the burrows with a slimy excretion they soon seemed quite at home. During the day they would be found with only the whorl of tentacles quietly protruding at the surface of the burrow, where their colors so closely conformed to that of the sand that the casual observer would hardly notice their presence. Going into the laboratory at night I was interested to see the specimens greatly extended, half of the body protruding beyond the burrows and tentacles raised in an attitude to seize passing prey. This was frequently observed afterward, and notes made of it at the time were recorded in which it was remarked that "these creatures are probably nocturnal in their habits."

At the same time I had under observation another anemone, *Sagartia leucolena*, a very common species about Woods Holl, and it was seen to migrate at times into darker portions of the aquarium, even creeping under bits of rock or other objects.

No further observations were made on the subject till the current summer. About a dozen specimens of *Eloactis* were collected and placed in the aquarium as before, and with the same

[1] Contributions from the Zoölogical Laboratory, Syracuse University.

result that such specimens as found sand proceeded to cover themselves as far as possible. In the light of current activity and interest in the matter of behavior it occurred to me to subject these creatures to a few experiments with a view of testing their reaction to light, and perhaps a few other environmental factors.

An examination of the available literature has brought to light but few instances in which any observations have been made concerning the behavior of actinians in relation to light. The Hertwig brothers, '79 ("Die Actinien Anatomisch und Histologisch," p. 191), cite brief observations made by Quatrefages on species of *Edwardsia* in 1842, and by Haime on *Cerianthus* in 1854, and include likewise brief references to their own observations on a deep sea-anemone, *Cladactis costæ*, in the Naples aquarium.

Quatrefages found that when a ray of light from a lamp was condensed upon the specimens by means of a lens they partially retracted. Haime observed that in bright sunlight species of *Cerianthus* contracted within their tubes and later expanded when the light became less intense. The Hertwigs record simply the fact the specimens during full daylight were more or less contracted and expanded as the light became less intense. "Im tageslicht zieht sie ihren Korper stark zusammen und erst wenn es zu dunkeln beginnt, dehnt sie sich auf das Vier- bis Funffache aus und entfaltet ihre Tentakeln, di zuvor eingezogen waren."

Jourdan has recorded a similar observation ("Les Sens chez Les Animaux Inferieurs," Paris, 1889), made upon a species of *Paractis* in which similar behavior was exhibited. "J'ai pu voir moi-même, sur des Actinies du genre Paractis, des manifestions évidentes de cette sensibilité spéciale. Des Orties de mer restent fermées aussi longtemps qu'on les expose à une lumière trop vive ; alles ne o'epanouissent que lorsqu'on les met à l'abri des rayons lumineux" (p. 221).

Eloactis producta. — My first observations were made to confirm those already cited, namely, to clearly demonstrate their nocturnal habit. Placed in the aquaria of the general laboratory, and in a few cases in smaller jars in my private laboratory,

their behavior was closely watched after the specimens had become adjusted to their new habitat. In this connection should be mentioned the fact, to be discussed later, that some specimens were much less prompt in burrowing, a few remaining more or less indifferently upon the surface of the sand and showing but slight attempts to bury themselves.

It only required a few observations to determine beyond any doubt that only in light of low intensity, such as twilight, or in the aquarium under the rather dim light of an incandescent lamp at some distance, did the specimens protrude their oral portions and tentacles and show any degree of activity. To further demonstrate that these seemingly nocturnal activities were not merely a periodic response made at more or less definite intervals, the following experiment was made. A tall glass jar, some twenty inches in depth, the lower third of which was filled with sand, in which had been placed several anemones some two days previous, was so placed on a laboratory table that it was freely exposed to the diffused light of the room. Over the jar was placed about mid forenoon, when the creatures were securely withdrawn in the burrows, a blackened chamber or dark hood, so arranged as to exclude more or less perfectly the light. Removing the hood at the end of an hour it was found that the creatures were quite extended as at night. And it was soon evident, that with the removal of the hood and the admission of light, they were at once aware of the change and promptly began to show signs of irritation, which ended within five minutes in every specimen having retracted into its tube. To make certain that the response had not been induced by some mechanical stimulus, such as the tremor of passing steps, or an accidental disturbance of the table or the water in the jar, the experiment was repeated within a half hour and under conditions which made it possible to observe the phases of the response.

Within fifteen minutes after the chamber had been placed over the jar it became quite evident that the change had been recognized by the specimens. This was shown first by the extension of the tentacles, and next by a slow protrusion of the oral region by degrees, till within about half an hour the body was extended an inch beyond the surface, as before. Again removing the

chamber and thus exposing the specimens to the light, within two minutes, indeed, almost immediately, they began to retract. This reaction is not sudden or general at once, as in such creatures as the earthworm, but begins in a somewhat indefinite movement of the body, accompanied by similar movements of the tentacles, followed very soon by a slow but definite retraction of the entire body within the tube, often including likewise the tentacles as well.

The experiment was later repeated in a room where it was possible to utilize direct sunlight. Under these conditions the reaction was much more energetic and definite, as might be expected. Variously modified, the experiments were performed repeatedly, perhaps fifty times, and with substantially the same results, though, as will be noted in a later connection, exhibiting variations of response. In some cases the reaction was so definite and prompt as to leave the impression on the observer that the creature was possessed of something akin to visual sensation. At other times the reactions were indefinite, sluggish, variable, and less convincing, though in the end resulting in the retraction of the specimen as before.

The following experiment was made to determine the extent of the sensory area, or in other words whether all portions of the body were similarly responsive to light. A specimen which had been quietly expanded on the surface of the sand for some time, being one of those which had shown less aptitude for burrowing, was so placed as to make it possible to reflect a narrow ray of light upon sharply defined parts of the body or tentacles. It was found that the oral region, including about one third of the body, was distinctly more sensitive than was any other. Light concentrated on the aboral portion seemed to have no effect at all, or so slight as to be indistinguishable. The tentacles were apparently less responsive than the immediately adjacent oral part of the body. This is slightly different from the condition found in *Sagartia modesta*, as will be noted later, and was a matter of some surprise, since the pigmentation of the tips of these organs might be thought to have some relation to sensory functions.

In a general way these results confirm the histological studies

of the Hertwigs (*op. cit.*, p. 22), as to the distribution of the sense cells in actinians. They also agree substantially with some of their experimental observations as to the unequal distribution of the sensory areas, though on this point they gave slight attention to the effect of light as a stimulus (*ibid.*, p. 190).

Sagartia modesta. — This anemone has much in common with the former species. It is a creature having its habitat in the sand just below or near low tide line. Like the former it takes somewhat readily to the artificial environment of the aquarium, though seems somewhat less hardy under these conditions. I first studied this species in its native haunt, having found several specimens on an accessible beach. I first found them just before twilight, and in the shadow of a large boulder which still further reduced the light, with the tentacles extended very much as in the case of *Eloactis;* the body was not protruded beyond the tube. Going again in the brightness of early morning they were not to be seen, no sign of tentacles even in the partially closed burrow. I made these observations several times, and concluded that they were probably also nocturnal.

Specimens were collected and taken to the laboratory and placed in the same general conditions as were the former species. Experiments similar to the former were performed, but with much less promptness or clearness in reactions. Placed under the dark chamber there was not the ready extension of the body as in *Eloactis*. Further, on removal of the hood the response was much less sharp and convincing, though quite evident. Placed on a table upon which a beam of sunlight could be reflected it was found when the ray was reflected upon the numerous tentacles that there was immediate reaction. It should be stated that in this species the tentacles are very numerous, even a hundred or more, and form a dense crown in expansion covering the oral region like an umbrella, while in the former species these organs are but twenty in number and rather short. In *Segartia* the tentacles seemed more sensitive than in the former species, or than the oral region, but this may be due in some measure to their numbers, and to the general relations they sustain to the oral portion of the body, especially the region just below the tentacles. Still the results agree again with the

views of the Hertwigs, as expressed in the following words: "Die Sinneszellen finden sich im Ektoderm der Mundscheibe und der Tentakeln, wie uns schien, überall ziemlich gleichmässig vor; nur an der Spitze der Tentakeln mochten sie vielleicht in grösserer Anzahl vorhanden sein" (*op. cit.*, p. 22).

Similar experiments were made on three other species of anemones, namely, *Sagartia leucolena*, *Sagartia luciæ*, and *Metridium marginatum*. These species are all more or less free, and variable as to habitat. The first, *S. leucolena*, is fairly common at various points along the shore-lines of the region of Vineyard Sound and southward. Its usual habitat seems to be under rocks near low tide, though taken also on the piles of docks. It seems to seek the under sides of rocks, or settles among masses of *Molgula*, sponges, etc., on piles, thus more or less secluded, and seldom seen by the casual observer.

On the other hand, *S. luciæ* seems to be equally at home almost anywhere in shallower pools, on fucus, piles of docks, etc., sometimes in shaded places, but oftener in the open sunlight on rocks, fucus, etc. About the same may be said of *Metridium*. While more common from deeper water than either of the others, it is yet quite common just below tide line on rocks, piles, etc.

The experiments on these species were made under the environment of the aquarium, but were sufficiently varied to give fairly satisfactory tests as to their reactions to this class of stimuli.

From what has been said as to the habitat just given it might be inferred that *Sagartia leucolena* would prove the more responsive to the tests, and such was found to be the case without exception, though as in the former cases, with considerable individual differences.

Verrill long ago pointed out that this species was more active when in dimly lighted aquaria, or at night. However, I have not found that specimens in the general light of the laboratory showed any very evident light reactions. But when an aquarium was placed in direct sunlight there was an almost uniform attempt on the part of specimens to escape from the direct rays. As a rule this was done by slowly creeping over the edge of the stone or shell into a less exposed position. Specimens which were in glass jars, and attached to the sides or bottoms of the jars, when

brought into direct sunlight soon closed up entirely, withdrawing even the tentacles, and assuming a more or less hemispherical shape. Taken from the direct light into the diffused light of the room they promptly expanded and remained so until again placed in the sunlight. This experiment was repeated again and again, and with substantially the same results. It was also found that the degree of contraction was very closely an expression of the degree of light intensity.

Many specimens were brought to the laboratory adhering to small rock fragments, bits of shells, etc. In a few cases when such specimens were exposed to direct light they would creep over to the shaded side of the rock, and during the night return to apparently the exact spot previously occupied. This might be taken to suggest some such sense of position as is known to be had by certain gasteropods; but the tests were not sufficiently numerous nor constant to warrant any definite statement.

With *Sagartia luciæ* and *Metridium* the case was very different, as might be expected. Specimens of these anemones placed under the same conditions as the former, indeed in many cases when occupying the same aquarium, were found to be almost without exception, quite indifferent to light. Placed for some time under a dark hood and suddenly exposed to direct sunlight there was not the slightest evidence that there was any sense of the change. The experiment was made in various ways. Sometimes as just suggested. Again, a beam of strong light was reflected directly on the specimen as it was quietly expanded on the table, but so far as *S. luciæ* was concerned, always and without exception, with negative results. Occasionally, though always doubtfully, *Metridium* would show some slight sensory movements of the tentacles. But specimens have been subjected to the reflection of a strong beam of light directly upon the oral surface for ten minutes at a time without the slightest response.

I have had a few specimens of *Edwardsia elegans* in the aquarium but for some reasons they did not seem at ease under these conditions, and exhibited no distinct evidence of any photic sensibility. I have seen but once any living specimens of *Cerianthus* at Woods Holl and then only under circumstances which rendered any observations impracticable. I regret therefore,

not to have been able to test the sensory behavior of these species.

The only other aspects of behavior which have been observed are those of feeding, and the very variable reactions concerned in tube-building.

Concerning the former my first experiments were made several years since. At that time I tested their feeding propensities by trying in various ways to induce them to take food. At various times during their aquarium life I tried to feed the creatures with bits of crab meat, bits of fish, clam, etc., but in no case was I able to induce the creatures to take the bait. During the present summer I observed that specimens of *Eloactis* which had been dug up and placed in a pail along with specimens of *Balanoglossus* were found devouring the latter alive. This was so unlike the former behavior that one was tempted to wonder whether they might have peculiarities of diet, and that their habitat on these sand flats, where likewise *Balanoglossus* has its home, might sustain some relation thereto. I therefore repeated the former experiment of offering them shreds of crab and fish meat and with the same negative results. I then tested them again with the *Balanoglossus* and found that it was taken quite readily by the same specimens which had refused the other bait. Leaving them for several days they were again tested with the same foods and with the same negative results. Having no specimens of *Balanoglossus* at hand some annelids, *Hydroides*, were offered them alive, and they were readily taken by three out of four tested.

No further qualitative tests were made along this line, but it would seem as if they were rather partial as to feeding habits, and particularly as to whether it be living or otherwise.

Limited tests were made as to their reaction to such substances as blood of crabs, clams, etc., but there seemed hardly any definite reactions indicative of olfactory, or gustatory sensibility. The swallowing reaction of *Eloactis* is much as in other species of actinians, namely that it consists largely of oral efforts. The tentacles play but little part in the reaction, though serving to press the food down upon the oral margins or lips. The swallowing act in these creatures involves something of a peristalsis of

the esophagus. It was observed in several instances that any considerable irritation of a specimen during the swallowing process was almost invariably followed by a reversion and ejection of the food. A worm three fourths swallowed would be ejected by a sort of antiperistalsis, which was more rapid than the swallowing had been.

From what has just been stated it need hardly be observed that attempts to feed specimens with bits of blotting paper, or other such materials, were uniformly negative in character.

The feeding experiments with other species were too limited to justify any special attention in this connection. In most cases no difficulty was encountered in inducing species of *Sagartia* to take food of almost any sort.

Burrowing Reaction. — Attention has been directed in an earlier connection to the fact that considerable variability is evident among various specimens as to the matter of burrowing, or tube-building. It may not be without some interest to briefly cite a few details along this line. It is one of the curious features in the activities of *Eloactis* that among a dozen specimens put into an aquarium the most remarkable difference of behavior in this respect may be seen. Most will show early signs of activity, and soon bury their bodies as completely as possible, and assume an erect position. Others appear to go through the efforts but in a most futile way. Left over night the aquarium will show in the tracks over the surface of the sand the varied movements made in this way. Still other specimens seem to show no effort whatever to burrow, but lie indifferently upon the surface, hardly showing signs of life except as they are stimulated by some means. This may continue somewhat indefinitely. But after a time a change may come over one of these sluggish specimens and it sets about constructing a burrow all at once, as it were, and within a night will have taken up the characteristic attitude of its kind. If now it be dug out and left again upon the sand it may promptly readjust itself again in a burrow, or it may remain for some days in the same indifferent aspect. Specimens which first bury themselves are usually prompt to build fresh burrows if dug out of the earlier ones.

The facts herein portrayed suggest several interesting inferences and inquiries by way of conclusion.

1. It seems clear that in the behavior of actinians toward light one is forced to recognize that certain species have sensory perceptions of photic stimuli quite as well defined as exist in such organisms as the earthworm, clam, etc. And while in this group of cœlenterates no such definite sensory organs are known as those found in many medusæ, the Hertwigs have described certain ectodermal cells which they have designated as sensory in function. It is not without some warrant that we may conclude that the various aspects of behavior under consideration are more or less definitely correlated with sensory structures and perhaps nerve cells.

2. Loeb, who has studied certain aspects of the behavior of *Cerianthus membranaceus* ("Physiology of the Brain," pp. 56–59), attributes them to the influence of two tropic forces, namely, geotropism and heliotropism. "Positive geotropism and positive stereotropism cause the Cerianthi to burrow in the sand vertically, and positive geotropism keeps them permanently in the burrow."

I have elsewhere shown the inadequacy of this explanation as applied to tube-dwelling annelids. I believe the facts under review may likewise be better understood and more consistently explained by other modes. Certainly the factor of light must be reckoned with as potent in the behavior of the several species studied. Again the variable behavior of these creatures in their burrowing habits is not easily accounted for on the usual theory of tropisms. Furthermore, it seems highly probable that in some cases the food-taking habit may sustain a relation to the general tube-dwelling habit.

3. Finally, as one considers the interesting facts as to the distribution of these light-reacting anemones the foregoing inferences are strongly corroborated. It is not necessary to review these facts in detail. It will be recalled that the observations of Quatrefages and Haime, already cited, had to do with species of *Cerianthus* and *Edwardsia* both of burrowing habit. Those of the Hertwigs were made on a species of *Cladactis*, an inhabitant of the deep sea. The observations of Jourdan were made on a species of *Paractis*, whose habit is not given, though species of this genus taken by the Challenger Expedition were also from the deep sea.

Of the species which have come under my own observations as light-perceptive, two are tube-dwelling, and one free-living, but secreting itself under various forms of cover, or occasionally burrowing in sand. Certainly neither geotropism nor stereotropism are equally or reasonably applicable as explanations of all these varied conditions and habits. I believe we are therefore forced to the conclusion that physiological conditions of adaptation are primarily involved, and that the various phases of behavior are so many expressions of such adjustments.

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